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VALIDATION OF NEW INDEXES OF MEASUREMENT: RELATIONSHIP OF RATE OF CHANGE PARAMETERS TO TASK PERFORMANCE UNDER STRESS

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FOREWORD

Part of the Biomedical Data System supporting the Apollo program involves the processing of EKG measurements. Recent developments in the area of new physiological parameters of measurement include rate of change and rate of rate of change approaches to the analysis of heart beat rate data. Basic studies have yielded promising results. However, before including these indexes in the cluster of biomedical measurement techniques to be applied during the Apollo missions, more should be known of their relationship to actual subject performance.

In this study, the rate of change techniques were refined and evaluated for use in real time monitoring of manned Apollo missions.

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INTRODUCTION

New indexes of measurement of psychological parameters are currently being developed. Of particular interest are the measurements of rate of change (RC) and rate of rate of change (RRC) in physiological functions and systems. Although preliminary research has shown that information is produced by RC and RRC measurement which is different from, and supplementary to, the more traditional measures (such as means and variances), the relationships of such information to the actual performance of individuals are not known. This present research consists of an experimental study in which, under stress as opposed to non-stress conditions, the characteristic RC and RRC of heart rate is related to proficiency in performing psychomotor and cognitive tasks of various levels of complexity. The eventual use of such information will be in establishing selection standards, and in the early detection and, particularly, prediction of adverse changes in the performance of astronauts during space flights.

The feasibility of the proposed study is supported in part by two previous research efforts. First, in a study of spontaneous activity, Lacey and Lacey found that individuals with a high rate of change (chacterized as "labile" persons) tended to show more errors in various experimental tasks than did individuals with a low rate of change (characterized as "stabile" persons).[1] Second, as Townsend and Lindsey have pointed out, one of the more provocative statistical treatments of physiological data is the determination of the rate of change and the rate of rate of change of the particular parameter studies.[2] Townsend and Lindsey have demonstrated the feasibility of measuring these two parameters and of determining their statistical significance both between and within subjects.

Rate of change and rate of rate of change indexes may be derived from instantaneous heart beat measures. Therefore, it was thought to be highly probable that the relationships between subjects with various levels of RC and RRC of heart rate and their performance on various tasks would be observable and be statistically significant. Further, support was thought to be highly probable for the hypothesis that subjects with high RC and/or RRC, characterized as "labile," would show significantly poorer performance under stress on various tasks than subjects characterized as "stabile," i.e., low RC and/or RRC. This then, is the major thrust of the present study.

Organisms show characteristic patterns of rhythmic activity. The more striking of these are arcadian rhythms, in which

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[1] Lacey, J. I., and Lacey, B. C. The relationship of resting autonomic activity to motor impulsivity. In: Solomon, H. C., Cobb, S., and Penfield, W. (Eds.) The Brain and Human Behavior. Baltimore: The Williams and Wilkins Co., 1958.

[2] Townsend, J. C., and Lindsey, J. F. Rate of change and rate of rate of change of physiological parameters: Their significance and evaluation. NASA working paper, Space Medicine, OMSF, NASA Headquarters, Washington, D. C., 1965.

internal processes regularly occur as if programmed to external (light - dark cycles, temperature, etc.) or internal (bodily processes) clocks. But, in addition to these more readily observable and somewhat striking rhythmic behaviors, there are other more subtle rhythms which are involved in human behavior. Granit has referred to these "spontaneous activity, a spontaneous discharge of neural elements."[1] He perceives such a fluctuation as being important in the maintenance of the optimum level of central nervous system functioning in the organism, and which enables it to respond to external stimuli as they themselves vary in intensity.

Both intra and inter-individual differences are manifested in the spontaneous discharges of the various systems of the human organism. As demonstrated by Lacey and Lacey, an individual may be quite stabile in electrodermal activity, and at the same time be labile in heart rate beat or electroencephalographic responses. Lability in one response system does not necessarily indicate lability in other systems.[2]

In addition to the studies of Lacey and Lacey, there have been other studies that relate to this problem. Malino and Shagass found that psychiatric patients demonstrated greater heart beat rate variability than other patients.[3] Uhlenbruck

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[1] Granit, R. Receptors and sensory perception. New Haven, Conn.: Yale University Press, 1955.

[2] Ibid.

[3] Malino, R., and Shagass, C. Physiologic study of symptom mechanism in psychiatric patients under stress. Psychosom. Med., 1949, 11, 25-29.

reported that he could induce a response to "psychic" stimuli only in subjects who were labile (i.e. those who showed a high degree of spontaneous activity).[1] There have been a large number of studies that relate spontaneous fluctuations in electrodermal activity and other physiological functions to measures of habituation of the orienting response.[2] This study is concerned with the validation of fluctuation in heart beat rate, with the validation of the rate of change and rate of rate of change parameters.

In the present study, the following four major hypotheses were tested:

1. Individuals characterized by high rate of change (RC) of heart beat rate under non-stress conditions will

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[1] Uhlenbruck, P. Plethysmographische untersuchungen am menschen. Die spontanschwankungen des extremitaten and der einflus der atmung anf dasselbe. Z. Biol., 1924, 80, 317-342.

[2] See:

A. Corah, N., and Stern, J. Stability and adaptation of some measures of electrodermal activity in children. J. exp. Psychol., 1963, 65, 80-85.

B. Martin, I. A note on reflex sensitivity and formation of conditional response. Behav. res. Ther., 1963, 1, 185-190.

C. Johnson, L. Spontaneous autonomic activity, autonomic reactivity, and adaptation. Rpt. 62-7, U.S. Navy Med. Neuropsychiat. Res. Unit., San Diego, Calif., 1962.

D. Stern, J., Stewart, M., and Winokur, G. An investigation of some relationships between various measures of the galvanic skin response. J. psychosom. Res., 1961, 5, 215-223.

E. Stern, J., Winokur, G., Graham, D., and Graham, F. Alterations in physiological means during experimentally induced attitudes. J. psychosom. Res., 1961, 5, 73-82.

F. Stern, J., Winokur, G., Stewart, M., and Leonard, C. Electrodermal conditioning: Some behavioral correlates. J. nerv. ment. Dis., 1963, 137-486.

G. Stern, J. Stability-lability of physiological response system. Ann. N. Y. Acad. Sci., 1966, 1018-1027.

perform more poorly under conditions of stress on three levels of tasks, respectively, taken from a psychomotor to cognitive continuum of complexity, than individuals characterized by low rate of change. (α = .05)

2. Individuals characterized by high RC under stress conditions will perform more poorly under conditions of stress on three levels of tasks, respectively, taken from a psychomotor to cognitive continuum of complexity than individuals characterized by low rate of change. (α = .05)

3. Individuals characterized by high rate of rate of change of heart beat rate (RRC) under non-stress conditions will perform more poorly under conditions of stress on three levels of tasks, respectively, taken from a psychomotor to cognitive continuum of complexity than individuals characterized by low rate of rate of change. (α = .05)

4. Individuals characterized by high RRC under stress conditions will perform more poorly under conditions of stress on three levels of tasks, respectively, taken from a psychomotor to cognitive continuum of complexity than individuals characterized by low RRC. (α = .05)

AN OVERVIEW OF THE STUDY

The experimental procedures devised to explore the hypotheses presented in the preceding pages are somewhat complex. They are presented, (in an overly simplified manner) at this point, so that when they are developed later in depth, their relationship to the overall design of the study will be more evident.

A group of subjects was secured in accordance with a number of stringently imposed criteria. Following final selection, each subject then was subjected to the experimental procedures on each of two successive days. On the first experimental day, rate of change of heart rate and rate of rate of change of heart rate measures were obtained. In this session the subject performed the perceptual, motor and cognitive tasks under non-stress conditions. Then, the subject's feelings in regard to the experimental situation were assessed, and a sample of urine obtained for catecholamine determination.

On the second experimental day, the subject was subjected to both physiological and psychological stress. The rate of change and rate of rate of change of heart rate measures were again secured, and the three experimental tasks were repeated. Then, in order to demonstrate that the subject reacted to the stress situation, his feeling state was again measured, and a post-stress urine sample obtained for catecholamine analysis.

The experimental procedures are summarized in Table 1, and then they are presented in detail in the following pages. First, the technique for the determination of the rate of change and rate of rate of change indexes are outlined. Second, the characteristics of the perceptual, motor, and cognitive tasks are detailed. Third, the manner in which the physiological and psychological stresses were induced is presented. Fourth, the procedures for the selection of subjects, and the manner in which they were categorized as "stabile" or "labile" subjects is discussed.

TABLE 1

OUTLINE OF EXPERIMENTAL PROCEDURES

OPERATION 1

Subject Selection

Phase 1: Initial Screening

Phase 2: Evaluative Study

OPERATION 2

Experimental Manipulation I, Non-stress Session

Rate of Change Measures

Perceptual, Motor, and Cognitive Tasks

Subjective Feeling State Assessment

Catecholamine Determination

OPERATION 3

Experimental Manipulation II, Stress Session

Stress Situation

Perceptual, Motor, and Cognitive Tasks

Rate of Change Measures

Subjective Feeling State Assessment

Catecholamine Determination

THE RATE OF CHANGE PARAMETERS

The rate of change (RC) index, which is a measure of how variable the heart rate beat is from one beat to the next, and the rate of rate of change (RRC) index, which is a measure of the degree to which the rate of change itself changes, the independent variables of the study, are relatively new approaches to the measurement of heart functions. Methods of determining these indexes, as well as suggestions as to their application to physiological and psychological data, have been presented by Townsend and Lindsey.[1]

The rate of change index of heart beat rate is determined by first obtaining a measure in terms of beats per minute, for each successive heart beat in a given time frame (instantaneous heart rate). Townsend points out that these data then are susceptible to statistical manipulation so as to yield an index of rate of change for a given subject. But he notes that even though the possibility of arriving at an index by applying the techniques of differential calculus to the data seems to be desirable at first glance, that the only part that may legitimately apply to such a procedure is the basic concept of using

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[1] See:
(a) Townsend, J. C. The measurement of rate of change and rate of rate of change of physiological data and the determination of their statistical significance. Unpublished Paper, Space Medicine, NASA Headquarters, Washington, D. C., 1965.
(b) Townsend, J. C., and Lindsey, J. F. Determination and evaluation of rate measurements in the analysis of space medical data. <u>Mult</u>. <u>behav</u>. <u>Res</u>., 1967, 2, 63-70.

the technique of differentiation in the production of rate of change and rate of rate of change information.

As Townsend states, the heart rate itself, from one point of view, may be assumed to be a first differential, but for the purposes of the present study it may be treated as basic data. He then proposes that the first differential, or the first set of differences, be calculated. This is done simply by subtracting the second heart rate from the first heart rate, the third from the second, and so on for each of the heart rate measures within a given experimental time frame during which the heart rate measures are accumulated. Then, these differences are added without respect to algebraic signs, since interest is only in the rate of change and not in its direction. The sum of the differences is then divided by the total number of differences, yielding the mean rate of change for the subject. This, as Townsend points out, may be considered in terms of calculus, as a non-directional derivative.

The rate of rate of change index is derived by calculating the second differential of the set of differences. The second rate of change score is subtracted from the first, the third score from the second, and so on for all of the rate of change measures within the given time frame. These are then summed, again without regard to sign, and then the sum is divided by the total number of rate of rate of change measurements. This ratio is then the mean rate of rate of change index for the subjects.

Townsend states that many other techniques were considered before concluding that this method was the best. These included: variability of the standard deviation (which was found to be too insensitive to RC data), the use of integral calculus to measure the area under the curve (which proved to be too complex a process), Fourier's analysis, the use of a power spectrum, and trend analysis. Townsend found that none of these proved to be as valuable as the technique of calculating the mean of a differential in producing RC and RRC information.

The basic data for calculation of the RC and RRC measures were secured by means of the techniques described in the following paragraphs.

First, the heart wave was recorded by means of a standard Sanborn electrocardiograph (the Viso-cardiette model). The machine was modified so that the standard paper speed of 25 mm. per second could be calibrated for each subject. Standard placement of the EKG electrodes was used, and the heart wave was recorded from lead #2. Each subject was required to recline quietly for a 15 minute period before the heart record was secured, and was not permitted to smoke.

Second, the distance from each pulse point to the next was measured to the nearest .2 mm. by means of a comparator providing for full 6 power magnification. This comparator was fitted with an etched glass rather than with a film reticle, which, due to its resistance to bending or warping, ensured a higher degree of accuracy of measurement.

Third, this distance was then converted, by means of a conversion table, into heart beats per minute, which provided the basic measure of instantaneous heart beat rate.

Fourth, the rate of change index was calculated by subtracting each heart rate from the preceding heart rate, summing the differences without regard to sign, and dividing this sum by the total number of differences summed.

Fifth, the rate of rate of change index was calculated by subtracting each rate of change measure from the preceding measure, summing the differences without regard to sign, and dividing the sum by the total number of differences summed.

The time frame for purposes of the experiment was a two minute period, and all heart beats during this time frame were utilized in calculating RC and RRC indexes.

THE EXPERIMENTAL TASKS

The dependant variables, with which the rate of change and rate of rate of change indexes of heart beat rate were related, were three measures of task performance, differing widely as to psychomotor and cognitive levels of complexity. Several considerations entered into the selection of the tasks. On of these was the desirability of selecting tasks which did not require an extensive pre-training of the subject. Another major consideration was the possibility of choosing tasks which approximated, in terms of the basic processes involved, many of the tasks that might be required of astronauts in orbital space flight. Also, it was mandatory that the tasks selected not be dependant upon previously learned skills of the subject. And, of course, it was required also that the tasks possess the requisite degree of reliability and validity.

Following an extensive task screening and review process, the following three types of tasks were selected:

(1) A sensory task, involving visual scanning

(2) A psychomotor task, involving tracking

(3) A cognitive task, involving abilities to manipulate thought processes into new organization and associations and to assimilate highly novel material

Each of these experimental tasks is presented in detail in the following pages.

The Perceptual Task

The task used to assess the patterns of perceptual response was a visual task based upon a modification of the technique originally described by Brown and his co-workers.[1] For purposes of the present study, a sheet of aluminum was carefully formed to a precise curve, being constructed so as to be an arc of a circle with a radius of 5 feet. It was painted flat black. In the center of the arc was placed a white jewel, behind which was a white 6.15 watt lamp (G. E. Lamp #605) powered by an input of 6.3 volts. On either side of this center white light three similar white jeweled lights were mounted. These subtended visual angles of 4 degrees, 16 degrees and 24 degrees, and were placed on the same base line. Three inches above the center white jeweled light a green jeweled light was mounted (G. E. Lamp #45).

A moveable chair, capable of being tilted almost to the horizontal position was placed in front of the apparatus, so that the center jeweled light was at eye level and 5 feet from the subject. Fastened to the arm of the chair was a telegraph key by means of which the subject responded. The apparatus which controlled the presentation of and response to the stimulus, was placed in an adjacent room, so that the subject would not be distracted by its operation or react possibly to secondary cues.

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[1] Brown, J. S., Bilodeau, E. A., and Baron, M. R. Bidirectional gradients in the strength of a generalized voluntary response to stimuli on a visual-spatial dimension. J. exp. Psychol., 1951, 41, 52-61.

The subject was not told the true nature of the experiment. The instructions which he was given were as follows:

> "Look directly ahead of you. You will see a green light come on. As quickly as possible after the green light comes on, push down this key and keep it depressed. When a white light comes on directly under the green light, release the key as quickly as possible. Also, you are to release the key if the green light goes out. It is important that you do this just as rapidly as you possibly can. Now, remember, when the green light comes on, push down on the key as fast as you can. Hold it down until a white light directly under the green light comes on, or if the green light goes out, then release it immediately. It is extremely important that you work just as fast as you possibly can. Do you understand?

Thus, the impression was given to the subject that the task was one of reaction time, whereas in essence it was concerned with determination of the frequency of false responses made by the subject to the peripheral lights.

A total of 166 trials was given. First, a series of 20 center light trials was presented. Then, each peripheral light was presented 5 times in a randomly determined manner, each being preceded by either 3, 4, or 5 center light trials, which were also randomly determined. Each light flashed for a period

.01 seconds. The inter-trial time interval was in every instance 10 seconds. This procedure was controlled by a partially automated apparatus, and each subject received an identical task program. The order of presentation of the lights, together with the varying time interval between the green and white light presentation is summarized in Table 2. The lights are numbered from left to right, and the center light is number 4.

Lacey and Lacey, in a stimulus-generalization experiment have used a similar task in investigating certain aspects of resting autonomic activity.[1] Subjects respond erroneously to the peripheral lights, and Lacey and Lacey state that the frequency of such erroneous response is an inverse function of the size of the visual angle subtended by the peripheral position of the light. They believe that this is an empirical form of stimulus-generalization in the spatial dimension, and that the act of erroneously responding is an integrated sensorimotor act involving both recepto-cortical and cortical-effector activities. Lacey and Lacey point out that the relative importance of these may be analyzed in terms of what they call the "generalization gradient." Their findings indicate that the frequency of erroneous responses decreases as the subtended visual angle of the light increases (as the lights approach the periphery of the arc). Therefore, if false responses occur due to defective

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[1] Lacey, J., and Lacey, B. C. The relationship of resting autonomic activity to motor impulsivity. In: The brain and human behavior. H. C. Solomon, S. Cobb, and W. Penfield (Eds.) Williams and Wilkins Co., 1958, pp. 144-209.

TABLE 2

SCHEDULE OF PRESENTATION OF PERCEPTUAL STIMULI

Trial No.	Light No.	Time Interval (Secs.)	Trial No.	Light No.	Time Interval (Secs.)
1	4	5	22	4	5
2	4	4	23	4	5
3	4	3	24	4	3
4	4	3	25	4	4
5	4	3	26	4	3
6	4	4	27	5	5
7	4	5	28	4	3
8	4	5	29	4	4
9	4	4	30	4	3
10	4	4	31	4	5
11	4	3	32	7	3
12	4	5	33	4	4
13	4	5	34	4	3
14	4	4	35	4	3
15	4	5	36	5	3
16	4	5	37	4	3
17	4	4	38	4	5
18	4	3	39	4	5
19	4	4	40	4	5
20	4	4	41	6	4
21	3	3	42	4	4

TABLE 2 (cont'd)

Trial No.	Light No.	Time Interval (Secs.)	Trial No.	Light No.	Time Interval (Secs.)
43	4	4	64	4	5
44	4	4	65	4	5
45	4	4	66	4	3
46	3	3	67	6	4
47	4	5	68	4	5
48	4	3	69	4	3
49	4	5	70	4	5
50	4	4	71	2	4
51	4	4	72	4	5
52	7	4	73	4	3
53	4	4	74	4	4
54	4	3	75	4	5
55	4	5	76	3	4
56	3	3	77	4	5
57	4	4	78	4	4
58	4	5	79	4	5
59	4	5	80	4	3
60	4	3	81	4	3
61	4	4	82	5	3
62	2	5	83	4	4
63	4	3	84	4	3

TABLE 2 (cont'd)

Trial No.	Light No.	Time Interval (Secs.)	Trial No.	Light No.	Time Interval (Secs.)
85	4	4	106	4	5
86	4	4	107	7	3
87	4	5	108	4	5
88	1	3	109	4	5
89	4	4	110	4	4
90	4	3	111	4	4
91	4	4	112	4	5
92	4	3	113	5	5
93	4	4	114	4	3
94	5	5	115	4	3
95	4	3	116	4	3
96	4	4	117	1	4
97	4	3	118	4	4
98	3	5	119	4	5
99	4	4	120	4	3
100	4	3	121	6	4
101	4	4	122	4	4
102	4	4	123	4	5
103	6	5	124	4	3
104	4	5	125	1	5
105	4	5	126	4	5

TABLE 2 (cont'd)

Trial No.	Light No.	Time Interval (Secs.)	Trial No.	Light No.	Time Interval (Secs.)
127	4	4	147	4	5
128	4	5	148	4	4
129	4	5	149	4	5
130	2	3	150	2	4
131	4	3	151	4	5
132	4	4	152	4	4
133	4	3	153	4	5
134	7	4	154	4	3
135	4	3	155	4	4
136	4	5	156	6	5
137	4	3	157	4	5
138	4	5	158	4	5
139	1	4	159	4	3
140	4	3	160	4	3
141	4	3	161	4	3
142	4	3	162	7	4
143	4	3	163	4	5
144	4	4	164	4	5
145	2	4	165	4	4
146	4	5	166	1	4

sensory discrimination associated with heightened receptor-cortical readiness to react, then there should be a negative correlation between the heights and the "slopes" of the response gradient. The frequency of occurence, as Lacey and Lacey point out, should be associated with "flat" gradients, in which the peripheral placement of the light does not have a sharp effect on the ratio of false responses to a given light. This relationship, in the study completed by Lacey and Lacey, was not found to hold.

The Psychomotor Task

In many studies psychomotor performances have been assessed by means of a tracking task. Two basic variations of this technique have been utilized: compensatory and pursuit tracking. A typical example is the rotary pursuit task, presented by Melton, which was developed for the Army Air Force.[1] In the present experiment motor functions were assessed by means of a target-pursuit task. The specific instrument employed was the new and improved Marietta Illuminated Target Pursuit Apparatus (Catalog Number 5-100).[2] This apparatus is designed so as to present a wide range in both variability of target movement (4" to 6" radius) and in target size (3/8" to 1"). It employs a rotating light source housed underneath a top panel, which projects a spot of light onto a translucent fiber glass top, and this

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[1] Melton, A. W. (Ed.) Apparatus tests. Washington, D. C., U. S. Govt. Printing Office, 1947, (AAF Aviat. Psycholo. Prog. res. Rep. No. 4).

[2] Marietta Apparatus Co., Marietta, Ohio, U.S.A. 45750.

luminous spot then becomes the target that the subject is required to track. The target assembly is housed in a metal cage. It includes: a 60 r.p.m. motor, a photocell amplifier, and an on-target buzzer, which may or may not be employed by the experimenter. The probe, by means of which the subject tracks the moving light target, consists of a lucite light-pipe and photocell assembly of adjustable sensitivity. The pursuit apparatus was connected to a low current impulse counter (Marietta #24-25), which recorded the number of times the subject hit the target (HIT). This counter was capable of being activated by a contact of only 2 milli-seconds duration, and had a maximum rate of operation of 1800 counts per minute. These specifications were far beyond those required by the study. In addition, the pursuit apparatus was connected to a stopclock, which recorded the cumulative time that the subject maintained probe contact with the target (TOT).

The radius of the target movement was set at 3 5/8 inches, and the diameter of the target size was set at 3/8 inches.

The subject was instructed as to the nature of the task, and was told that he would know when he was in contact with the target by the sound of the buzzer. He was then given a 10 second training period, followed directly by the experimental session, which lasted for a period of two minutes.

Three indexes of performance were secured for each subject:

(1) Total time on target (TOT)

(2) Total target hits (HIT)

(3) Total time on target divided by total number of target hits (TOT/HIT)

The Cognitive Task

Cognitive functions were assessed by means of the Obscure Figures Test, Form 1. This test was devised by McReynolds and Acker, and was first published in 1965.[1,2] It is comprised of 40 drawings, which in general are quite ambiguous. The subject is required to treat these figures as stimuli, with the instructions to make a response that is as "clever, unusual and imaginative" as possible. McReynolds and Acker state that the Obscure Figures Test is designed so as to measure the individual's tendency to be innovative. They define innovation as the process of "forming novel concepts, ideas, and products," and view the innovative person as "one who seeks novelness, newness, differentness, who is inclined to see and to conceive of things in unusual and original ways, and who is able to modify or elaborate the usual so that it becomes different and novel." Thus, the test is designed so as to assess the individual's capacity to be innovative, and is to be regarded as a measure of cognitive innovation. According to Acker and McReynolds, this is the process through which the individual alters his structure of reality in order to include new data, in terms of which "input" data are processed. It is a type of restructuring, which has

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1 McReynolds, P., and Acker, M. <u>The Obscure Figures Test, Form 1. Manual for administration and scoring.</u> Behavioral Research Laboratory, Veterans Administration Hospital, Palo Alto, California, Research Report No. 34, 1965.

2 Acker, M., and McReynolds, P. The Obscure Figures Test. An instrument for measuring cognitive innovation. <u>Percep. mot. Skills</u>, 1965, 21, 815-821.

two major functions. First, it aids in the assimilation of perceptual material which otherwise cannot be integrated; and second, it maintains perceptual variability and novelty at an optimum level. Thus, cognitive innovation essentially is concerned with originality, imagination, and ingenuity, and so consists to a large degree in the development of new ways of dealing with input data.

Acker and McReynolds have reported upon the reliability of the test scoring system.[1] They report that, in one sample of 50 subjects, that the correlation between total scores obtained independently by two scorers was .90. For an additional sample of 43 college students it was .85. If the Spearman-Brown prophecy for a test of doubled length (since there are two independent scorers) is applied, then the reliability of scoring, when the scores of the combined values obtained by the two raters are used, becomes, in the case of the two preceding studies, .95 and .92 respectively.

The following method of administration of the test was employed. The subject was given the following instructions:

> "On the sheets following this one, you will find a number of figures that could represent a variety of things. Your task is to write in the blank corresponding to the figure on the answer sheet something you think that figure could be. The drawings purposely are vague and indefinite,

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1 Ibid.

and there are no specific things they represent. In other words, there are no right or wrong answers.

Start at Figure 1 and go through them in order, without skipping around. If you come to a figure and you cannot think of something that it might be, write 'nothing' in the blank, and go on. TRY TO GIVE AS CLEVER OR UNUSUAL A RESPONSE AS YOU CAN -- but not one that is ridiculous -- it should be possible to imagine your answer from looking at the drawing. Just be as imaginative as you can -- you get extra credit for being creative. Work as fast as you can, and when you have finished, close your booklet, so that I know when you are done and can record your time."

When the subject indicates that he has finished the task, the time is recorded.

THE STRESS SITUATION AND VALIDATION

There is an abundance of experiments which show that performance on cognitive and psychomotor tasks is disrupted under stress.[1] The types of stress utilized in such studies have varied widely from one experiment to another. For purposes of the present study two types of stressors were utilized. The first was a physiological stressor. This was the threat of electric shock. The second was a psychological stressor, occuring as a result of the individual working against a "time to completion" limit, and the threat of inferior performance. In order to maximize the stress situation, the subject was exposed to both of these types of stress simultaneously.

First, the characteristics of the experimental stress situation and the manner in which it was induced will be discussed. Then, the techniques for validating the presence of a stress reaction by each subject included in the final sample will be presented.

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[1] For example, see:

a. Erickson, C. W., and Wechsler, H. Some effects of experimentally induced anxiety upon discrimination behavior. _J_. _abnor_. _soc_. _Psychol_., 1955, 51, 458-463.

b. Lazarus, R. S. A laboratory approach to the dynamics of psychological stress. _J_. _gen_. _Psychol_., 1963, 8, 192-213.

c. Parsons, O. A., Phillips, L., and Lane, J. E. Performance on the same psychomotor task under stressful conditions. _J_. _Psychol_., 1954, 38, 457-466.

The Physiological Stress

The physiological stress was established in the manner detailed in the following paragraphs.

The subject was told at the beginning of the second experimental situation:

> "Now today we are going to repeat some of the things we did yesterday, but I am afraid that this session will not be as pleasant an experience for you. First, let us put of the electrodes so that we can monitor your heart reaction. (Attach EKG electrodes). Now, we are going to put on some other electrodes on your leg. These electrodes serve quite a different function. Their purpose is to give you an electric shock that you will find to be very unpleasant. The shock will be quite painful.
>
> The first thing that we are going to do is to determine what you think is a painful electric shock. Now, I am going to give you a series of electric shocks. They will start at a relatively low level and increase in intensity as we procede.
>
> You are to use the key on the arm of your chair. When you feel the first shock, press the key. Do not press the key after any of

the other shocks until you feel that the shock you receive is definitely uncomfortable and very unpleasant. There is no need to be completely stoic, but I would like to know when you find the shock to be very pwinful. (Administer series of shocks in increasing intensity until the subject reacts by depressing the key.)

Now, you feel that the last shock was very uncomfortable?

The shock can be increased in two ways. First, the _intensity_ of the shock can be increased. Second, the length of time that it is applied can be increased. Either one of these procedures, or both together, will result in more discomfort or pain to you.

Throughout our experimental session today you will receive a number of electric shocks at _completely_ random intervals. I will now know when they will be given to you, or even know how many you will receive, but I _do_ know that you will receive several of them. Also, I know that they will all be of longer duration and of greater intensity than the one that you felt was painful. So they will all be more painful. In summary, you will receive several randomly spaced electric shocks of high intensity and duration, and all of them will be painful to you."

The Psychological Stress

The psychological stress was produced by changing the instructions given to the subject for each of the experimental tasks. These modified instructions are presented in the following paragraphs.

The Motor Task

The subject was given the following instructions:

> "Yesterday you were able to maintain contact with the light target for a period of __________ seconds. (The subject is given his actual time on target score.) Now, this is actually a very inferior performance for a college trained person. You ranked considerably below the average score for your group, so today I want you to really try to do better."

No electric shocks were administered during the motor task.

The Perceptual Task

The subject was given the following instructions:

> "Today we are going to repeat the test that you took yesterday, where you were required to react as rapidly as you could to the lights. As you do the same task

> today, I will be using an 'averaging' technique to compare today's performance with that of yesterday. If your performance falls down, you will receive a painful shock. So, if you receive a shock, you will know that your performance today is not as good as that of yesterday."

The subject is given a total of 5 electric shocks during the administration of this task. They are given to each subject on trials 5, 43, 65, 112, and 142.

The Cognitive Task

The Obscure Figures Test, which was used to determine cognitive functioning, was administered in accordance with the following procedures. The subject was told:

> "Yesterday you took ____________ to complete this test. (Give actual time.) Now this is a long time, and it is not quite as good as that of your peers. I am sure that you should be able to work much faster. The usual length of time for subjects in your group is about 5 minutes. So today I would like you to work much faster, although like yesterday, you will have all the time you need to finish the test. You will, however, receive random shocks while you work on it, so obviously the longer you take to do the

test the greater the risk is of receiving a painful shock. Now, to summarize, your performance yesterday was well below that of your group. You should be able to do much better, so try and work much more rapidly today. Since you will receive random shocks the less time you take the less risk you take of receiving painful shocks. Do you understand?"

The subject received a shock at the 2 minute and 4 minute points.

Validation of the Stress Situation

It is apparent that the particular type of stress situation employed was not the factor of primary importance for this experiment. Rather, what was of crucial importance was that all subjects, who were supposedly stressed by the experimental situation, <u>actually were stressed</u>. Too often, on a priori grounds, a situation is deemed to be stressful to all persons, and so is applied to a group of subjects. But it is dangerous to make such an assumption, since many studies point out that what is a stress situation for one person need not be stressful for another.[1] What primarily was of importance to establish,

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[1] Lazarus, R. S., Deese, J., and Osler, S. F. The effects of psychological stress on performance. Psychol. Bull., 1952, 49, 293-317.

then, was not that the group of subjects as a whole showed evidence of being stressed, but that each subject actually was stressed. Therefore, it was necessary that validation procedures be developed and applied so as to ensure that this was indeed the case.

Berkun, following examination of the published literature on stress, discussion with military consultants, and his own experimentation, has set forth operational criteria for experimental stressful situations.[1] These include: (1) subjective feelings of distress by the subject, and (2) indications either in the blood or urine of a disruption in normal bodily processes. These two validating criteria of stress were employed in the present study.

Subjective Feelings of Distress

The affective reaction of the subject to the stress situation was evaluated by means of the "Subjective Stress Scale." This scale was devised by Kerle and Bialek, with the first form of the scale being published in 1958.[2] The scale is an equal-appearing-interval Thurstone scale of 15 words, originally sorted into 11 categories by samples from the Army population to which it was first applied. It is, then, a series of quantitatively scaled words that indicate affect, and which

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[1] Berkun, M. M. Performance decrement under stress. Human Factors, 1964, 23, 21-30.

[2]. Kerle, R. H., and Bialek, H. M. The Construction, Validation and Application of a Subjective Stress Scale. Staff Memorandum, February, 1958, United States Army Leadership Human Research Unit, Presidio of Monterey, California.

extend from positive through neutral to negative affective states. The subject is required to select from the group of words that one word which closest categorizes his feeling state at the time of the experimental session. The scale was designed so that the neutral (or the middle point) on the scale is the word "Indifferent." This is assigned a neutral value of 48. The most positive-affect end of the continuum is represented by the word "wonderful," which has a scale value of 00. The most negative-affect end of the continuum is represented by the phrase "scared stiff," which has a scale value of 94.

In a later study (1958) Berkun, et al. demonstrated that the scale had a high degree of value in assessing the emotional responses of the subject to external environmental events.[1]

The Subjective Stress Scale continued to be used in the original form until 1962, when Berkun, et al. published a revised form.[2] The original scale contained the phrases "Terrible" and "In Agony." It was found that these were responded to in terms of physical distress (such as headache and/or insomnia), rather than being responded to in terms of the emotional event to which the subject was directed to respond. Therefore, the authors deleted entirely the phrase "In Agony," and for the word "Terrible" they substituted the word "Panicky."

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[1] Berkun, M. M., Timeras, P. S., and Pace, N. Psychological and physiological responses in observers of an atomic test shot. Psychol. Rep., 1958, 4, 679-682.

[2] Berkun, M. M., Bialek, H. M., Kern, P., and Yagi, K. Experimental studies of psychological stress in man. Psychol. Monog., 1962, 76, No. 15.

The list of words is presented to the subject in a scrambled order. Berkun, et al. state that they do not feel that an alternative or equivalent form of the scale is necessary. The 1962 revision of the Subjective Stress Scale was used in the present study.

Disruption of Physiological Processes

There is ample evidence to indicate that stress significantly affects the adrenomedullary system. The adrenal gland may be considered as a complex multiple endocrine organ consisting of two major structures. First, there is the adrenal cortex, which is associated with the elaboration of a number of steroids. Second, there is the medulla, which differs in its origin from the cortex. The cortex is derived from glandular tissue, while the medulla originates from neural tissue. Consequently, the medulla is closely related to the sympathetic nervous system.

Two hormones are secreted by the adrenal medulla. These are: epinephrine and nor-epinephrine. Both of these are amines, and are related to "catechols." Because of these relationships, they are referred to, in toto, as "catecholamines."

It has been established that a portion of the adrenal medullary hormones together with their metabolites is excreted in the urine. Therefore, through applying bioassay techniques to a urine sample the state of adrenal-medullary functions may be determined. Thus, the changing levels of catecholamines in the urine indicate change in activity of the adrenal gland.

Stress has been shown to result in an increase in the urinary excretion of catecholamines.[1] Frankenhaueser and Post also found that there is a significant increase in epinephrine excretion following stress.[2] Graham, _et al_. concluded that avoidable threats of electric shock which produced anticipatory stress reactions resulted in increased epinephrine excretion values (29 ng per minute).[3] Pekkarinen, _et al_. found that students being examined for admission to medical schools showed marked increase in epinephrine excretion, and that similar results were found for other types of examination.[4] Of interest is their finding despite the rise in epinephrine excretion, there was no rise in nor-epinephrine nor in 17-OHCS. These findings are supported by additional studies, such as those of the stresses resulting from manned space flight.[5]

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1 von Euler, U. S. Quantitation of stress by catecholamine analysis. _Clin_. _pharmacol_. _Ther_., 1964, 5, 398-404.

2 Frankenhaueser, M., and Post, B. Catecholamine excretion during mental work as modified by centrally acting groups. _Acta_. _physiol_. _Scand_., 1962, 55, 74-81.

3 Graham, L. A., Cohen, S. L., Shmavonoian, R. M., and Kirshner, N. Sympathetico-adrenal correlates of avoidance and escape behavior in human conditioning studies. _Psychosom_. _Med_., 1963, 25, 488-489 (abst.).

4 Pekkarinen, A., Castren, O., Iisalo, E., Koivusalo, M., Laihinen, A., Simola, P., and Thomasson, B. The emotional effect of matriculation examination on the excretion of adrenalin, nor-adrenaline, 17-hydroxy-corticosteroids in the plasma. _Biochemistry_, _pharmacology_, _and_ _physiology_. New York: Pergammon Press, Inc., 1961, pp. 117-137.

5 Jackson, C. B., Jr., Douglas, W. K., Culver, J. F., Ruff, C., Knoblock, E. C., and Graybiel, A. Results of preflight and postflight medical examinations. _Proc_. _Conf_. _on_ _Results_ _of_ _First_ _U.S_. _Manned_ _Suborbital_ _Space_ _Flight_, June 6, 1961.

The conclusion may be drawn that conditions of stress are accompanied by an increase in the secretion of catecholamines in the urine.

A review of the available literature reveals that the urinary secretion of catecholamines is affected by factors other than stress. There are three major conditions that are of importance in this regard. These are:

(1) Vigorous exercise prior to securing the sample of urine, which will greatly increase the catecholamine excretion.

(2) Disease processes, such as myasthenia gravis and progressive muscular dystrophy, which also increase catecholamine excretion.

(3) The effect of drugs, which elevate the catecholamine excretion. This is particularly true of all medications which serve to increase production of fluorescent urinary products. These would include such drugs as: drugs of the alpha methyldopa configuration, tetracycline, large amounts of the B vitamin complex or any adrenaline-like derivative.

It was important, therefore, that controls be instituted so that the possibility of spuriously elevated catecholamine readings be reduced. The effect of exercise prior to the securing of the urine specimen was controlled by the fact that the subject engaged in little (almost none) physical activity for a period of approximately three hours before the urine sample was obtained. The enhancing effects of disease and drugs were controlled by reviewing the medical history of the subject and eliminating all subjects with significant medical findings.

The urine sample for determination of catecholamine secretion was secured in the following manner.

1. Immediately upon arrival at the laboratory the subject was instructed to void urine.
2. Each subject then was given eight ounces of water to drink.
3. At the conclusion of the experimental session the subject then was required to void into a urine specimen jar, into which had been placed an acid preservative.

Identical procedures were followed for securing the urine sample on both experimental days.

Thus, a 2 hour urine was collected with 2 ml. of 6N HCL. This served to maintain the specimen at less than pH 2. The catecholamines were found to be stable for 4 to 5 days at room temperature and at least for 1 month when refrigerated.

The procedure followed for determination of catecholamines was the method of the Sobel and Henry Bioscience Laboratory.[1]

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[1] See:

a. Sobel, C., and Henry, R. _Am_. _J_. _clin_. _Path_., 1957, 27, 240-245.

b. von Euler, U. S., and Lishajko, F. _Acta_. _physiol_. _Scand_., 1959, 45, 122-132.

c. Bertler, A., Carlsson, A., and Rosengren, F. _Acta_. _physiol_. _Scand_., 1958, 44, 273-292.

d. Jacobs, S., Sobel, C., and Henry, R. _J_. _clin_. _endocrin_. _Metab_., 1961, 21, 303-314.

This was modified in the following way:

> The isolation of catecholamines was performed in 20x120 mm. screw cap tubes, and the catecholamines were eluted with the aid of a 45 rpm rotator.

Recovery studies were comparable to other methods, in that recovery values are between 79 and 90 per cent.

SELECTION AND CATEGORIZATION OF SUBJECTS

The subjects of the study were obtained from colleges and universities throughout the state of Virginia. They included students from the Medical College of Virginia, Richmond Professional Institute, the University of Richmond, the University of Virginia, and Virginia Polytechnic Institute. The process of subject selection was divided into three major phases:

(1) Phase One: Initial Screening

(2) Phase Two: Evaluative Study

(3) Phase Three: Experimental Manipulation

Each phase is discussed in detail in the following paragraphs, then the characteristics of the subject group finally selected are summarized, and next the manner in which the labile and stabile sub-groups were formed is presented.

Phase One: Initial Subject Screening

Advertisememts were inserted in college and university newspapers stating that subjects were being sought for an experiment. These notices stated that only male science or engineering majors above the age of 19 would be eligible. All interested persons were requested to contact the research office for an application blank. When a potential subject contacted the office, he was told that subjects were being sought for an experiment, but that he would be unable to be informed of any details of the study until it had been completed.

He was told that it would require approximately 8 hours of his time, to be divided into three sessions. The first session would be held at any suitable time, but that the remaining two sessions would need to be scheduled by the research office at the same time on each of two successive days. The subject also was told that he would be reimbursed for his time at the rate of $2.50 per hour, but that he would not receive payment if he, himself, voluntarily terminated his participation prior to the completion of the two experimental sessions. He was informed that certain criteria had been established for the selection of subjects, and that if he did not meet the criteria and so was not selected as a subject, that he would be paid for the time that he had put in. If these procedures were acceptable, he was requested to complete a personal history blank and a medical history blank. The information from these forms was then reviewed in order to determine whether or not the subject met the following criteria:

(1) Be of at least 19 years of age

(2) Be a science or engineering major

(3) Be free from any perceptual or medical disability that might interfere with the study.

If there was doubt as to the acceptability of the medical history, the subject was referred to the medical consultant for decision as to whether or not a significant disability existed. If all three selection criteria were satisfied, the person then was advanced to Phase Two for further evaluation.

No records were kept of the total number of persons contacted at this initial selection level. Some of the persons contacting the research office were not 19 years of age, some were not science or engineering majors, some had significant medical disabilities, and surprisingly, despite the clarity of the announcement, some inquiries were received from females.

Phase Two: Evaluative Study

Subjects were screened for both intellectual and emotional factors. The intellectual level was determined by the Otis Self-Administering Test of Mental Ability, Higher Examination, Form A. Reliability of the Otis test has been determined by means of correlations between different forms of the test (Forms A and B). When Form A was given first, the correlation was .917 $\pm$ .009, and when Form B was given first the correlation was found to be .925 $\pm$ .009. The average reported reliability measure was .921. The values of the probable error of a score determined from these groups were reported by Otis as 2.56 and 2.68 points respectively.[1] All potential subjects were required, for the purpose of this study, to score at least at the 80th percentile.

Potential subjects were screened for significant psychiatric and psychosomatic disabilities by means of the Cornell

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[1] Otis, A. S. *Otis self administering tests of mental ability Manual and Key.* (Revised) New York: Harcourt, Brace, and World, Inc.

Index. The Cornell Index is a direct descendant of the earlier Cornell Service Index, which was used extensively for military screening. The reliability of the index has been estimated by the Kuder-Richardson formula as being .95.[1] This was obtained by study of the records of 1000 subjects. All potential subjects were required to attain a score of 10 or less on the Cornell Index. According to the available norms, a cut-off score of 10 may be interpreted as meaning that 81% of the persons rejected for psychiatric disabilities at interview would also be rejected by the Index. Also, 18% of those persons accepted by the psychiatric interview, in addition would have been rejected.

If the potential subject met both of these screening test criteria, and if no further medical or other problem had been uncovered by interview, then he was scheduled for the experimental manipulation of Phase 3.

A total of 151 subjects was initially evaluated at the level of Phase 2. Of these, a total of 27 was eliminated for various reasons, leaving a total of 124 subjects advanced to the phase of actual experimental manipulation. The reasons for non-selection of subjects are summarized in Table 3.

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[1] Weider, A., Wolff, H. G., Brodman, K., Mittelman, B., and Wechsler, D. Cornell Index: Manual. (Revised Edition) New York: The Psychological Corporation.

TABLE 3

REASONS FOR NON-SELECTION OF SUBJECTS
(N = 27)

Reason	N
Did Not Follow Test Directions	1
Medical Disability	3
Severe Language Handicap	2
Too high C.I. Score	5
Too Low Otis Score	4
Voluntary Termination	12

Phase Three: Experimental Evaluation

All subjects selected for purposes of the study were required to show evidence in both psychological and physiological functions of a stress reaction to the experimental situation, in accord with the previously detailed criteria.

As previously stated, a total of 124 subjects, who had met all prior criteria was advanced to this final phase of the selection process, and subjected to the experimental procedures. Of these, 80 met the criteria for stress in both physiological and psychological functions, and so were qualified fully as subjects, while 44 of them did not do so. It should be noted that it was necessary to carry all potential subjects completely through all experimental procedures in order to determine whether or not they would be qualified as subjects, since the final selection rested upon the determination of the change in psychological and physiological measures from the non-stress to the stress conditions.

The Subjective Stress Scale scores achieved by each of the subjects in the non-stress and stress situations are summarized in Table 4. In each instance the stress score exceeds the non-stress score.

The amount of catacholamines excreted by each of the subjects in the non-stress and stress situations are summarized in Table 5. In each instance the stress index is higher than the non-stress index.

Subject Characteristics

The characteristics of the final group of subjects are presented in the following pages.

Age

The age distribution of the group of subjects finally selected are summarized in Table 6.

Intelligence

The distribution of Otis Scores (by percentile) is summarized in Table 7.

Inspection of the data summarized in Table 7 indicates that 72, or 90.00% of the subjects, scored at or above the 90th percentile. Therefore, even though the cut-off point was set at the 80th percentile, the final group of subjects actually achieved at a much higher level.

TABLE 4

SUBJECTIVE STRESS SCALE SCORES UNDER NON-STRESS AND STRESS CONDITIONS (N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	17	64	38	9	69
4	40	69	40	27	69
5	9	40	41	27	88
8	17	64	45	17	64
9	40	64	47	64	69
10	40	69	49	17	69
13	9	64	55	17	69
14	40	94	57	9	69
16	9	48	58	27	69
17	17	76	60	74	83
19	17	64	62	17	69
20	17	69	63	40	48
23	40	69	67	64	69
24	9	69	70	17	69
25	69	74	71	69	83
26	40	48	74	17	94
27	40	64	77	17	74
29	27	69	78	17	69
32	27	69	81	40	69
34	64	69	84	17	64

TABLE 4 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
86	77	27	115	69	74
87	64	69	120	40	69
88	9	76	121	40	69
89	17	69	122	40	69
90	97	64	123	40	64
94	27	69	124	57	83
95	40	69	125	17	64
97	9	69	132	9	69
98	9	69	134	17	64
99	17	83	136	17	69
100	40	69	137	64	69
102	17	64	138	57	69
104	27	69	141	48	64
108	64	69	143	27	40
109	40	69	144	9	69
110	17	64	145	17	69
111	40	69	147	9	40
112	17	74	148	9	64
113	48	74	149	40	48
114	27	69	151	17	64

TABLE 5

CATECHOLAMINE PRODUCTION UNDER NON-STRESS AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	6.0	1.4	38	1.6	8.1
4	1.5	2.6	40	.6	3.5
5	1.2	1.9	41	.1	4.8
8	1.1	1.2	45	.7	1.7
9	2.4	2.9	47	1.2	7.8
10	1.4	2.9	49	.7	1.3
13	1.3	1.4	55	1.0	1.4
14	2.0	2.8	57	2.6	3.6
16	.1	.7	58	3.4	5.4
17	.5	1.3	60	2.2	3.0
19	2.3	2.9	62	2.8	5.3
20	1.6	2.1	63	.7	3.2
23	1.1	3.4	67	2.6	6.0
24	1.0	2.1	70	2.3	3.5
25	1.5	2.9	71	.8	2.1
26	.6	2.5	74	1.0	3.4
27	1.0	2.3	77	1.1	2.2
29	1.2	4.4	78	1.6	4.1
32	.6	5.5	81	1.8	2.9
34	.7	4.2	84	2.1	13.4

TABLE 5 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
86	2.7	2.8	115	1.7	2.1
87	2.7	5.4	120	2.3	5.0
88	2.7	4.3	121	1.1	2.2
89	.8	7.1	122	3.2	5.1
90	3.2	3.6	123	2.4	2.7
94	2.3	4.8	124	1.1	3.8
95	3.2	5.6	125	2.0	2.7
97	6.0	9.5	132	2.5	5.0
98	1.1	2.1	134	.5	1.0
99	2.8	3.6	136	2.3	3.9
100	5.5	7.7	137	.6	.9
102	2.1	4.1	138	.5	1.5
104	2.8	5.2	141	.9	3.4
108	2.2	2.6	143	.5	1.5
109	1.9	2.2	144	.5	1.5
110	1.7	2.8	145	.5	1.1
111	2.6	2.7	147	.5	2.3
112	3.7	6.5	148	2.8	3.2
113	1.5	10.9	149	2.1	4.2
114	3.0	3.1	151	1.1	4.9

TABLE 6

AGE DISTRIBUTION OF SUBJECTS
(N = 80)

Age	N
19	29
20	24
21	11
22	4
23	2
24	1
25	2
26	3
27	0
28	1
29	2
30	0
31	1

TABLE 7

DISTRIBUTION OF OTIS SCORES
(N = 80)

Percentile	N
95-100	70
90-94	2
85-89	5
80-84	3

Emotional Stability

The distribution of Cornell Index scores is summarized in Table 8. Inspection of the data summarized in Table 8 indicates that 45, or 55.6% of the subjects attained a score of 3 or less, while 58, or 71.6% of the subjects, attained a score of 5 or less. Therefore, even though the cut-off Cornell Index score was originally set at 10 or less for purposes of the study, the group actually scored at a much lower level.

TABLE 8

DISTRIBUTION OF CORNELL INDEX SCORES
(N = 80)

Score	N
0	14
1	12
2	10
3	9
4	8
5	5
6	6
7	3
8	4
9	3
10	6

Rate of Change and Rate of Rate of Change Indexes

The rate of change and rate of rate of change indexes secured under non-stress and stress conditions are presented in Table 9. These indexes are presented for the group of 80 subjects meeting all the criteria of the study.

Formation of Stabile and Labile Groups

The task, following the accumulation of the final pool of 80 subjects, was to separate the subjects into stabile and labile sub-groups according to the non-stress and stress rate of change and rate of rate of change measurements. Since these parameters are relatively new, there are no normative data available to enable a determination to be made as to whether or not a given change index is to be categorized as either "stabile" or "labile." Accordingly, it was decided to approach the matter in the following manner.

First, the rate of change scores, and second, the rate of rate of change scores obtained for each subject under non-stress conditions were ranked, with the highest score being given the rank of "1." Third, the rate of change, and fourth, the rate of rate of change scores obtained for each subject under the stress conditions were similarly ranked. This resulted in four separate sets of rankings, two for the rate of change scores (non-stress and stress) and two for the rate of rate of change scores (non-stress and stress). Then, the highest 25% of each of these groups was categorized as "labile,"

TABLE 9

RATE OF CHANGE AND RATE OF RATE OF CHANGE UNDER NON-STRESS AND STRESS CONDITIONS (N = 80)

Subj.	Non-Stress RC	Non-Stress RRC	Stress RC	Stress RRC	Subj.	Non-Stress RC	Non-Stress RRC	Stress RC	Stress RRC
2	7.65	6.16	4.87	4.26	38	1.92	1.83	2.42	2.35
4	5.37	3.75	3.40	2.71	40	2.88	2.31	2.63	3.21
5	2.20	1.52	3.73	2.04	41	2.56	2.24	2.14	2.02
8	2.16	1.70	2.14	1.62	45	5.40	4.53	3.87	3.11
9	1.23	1.03	4.23	3.79	47	3.69	3.24	4.09	3.44
10	2.17	1.69	2.52	2.23	49	6.27	5.56	1.81	1.67
13	2.25	2.09	2.89	2.23	55	5.03	4.20	5.79	4.23
14	2.84	2.31	2.76	2.18	57	2.69	2.26	2.25	1.66
16	1.90	1.51	2.37	1.68	58	9.03	10.32	5.38	4.87
17	2.73	2.75	3.86	2.83	60	3.64	3.16	3.89	3.51
19	1.61	1.35	1.29	.92	62	2.41	1.87	2.29	1.92
20	3.11	2.53	2.38	1.97	63	3.29	2.28	4.21	3.20
23	2.67	2.11	4.06	3.49	67	3.60	3.06	3.51	2.71
24	3.34	2.54	4.28	3.07	70	4.16	3.39	5.36	5.44
25	4.70	3.69	4.23	3.35	71	2.78	2.65	2.04	1.71
26	2.11	1.87	2.88	1.93	74	4.18	3.44	3.00	2.67
27	2.78	2.70	2.98	2.36	77	3.54	2.31	3.77	3.74
29	2.48	2.05	2.16	1.79	78	4.91	4.17	6.47	5.49
32	3.27	2.55	3.07	2.61	81	5.70	4.72	5.91	4.89
34	2.22	2.13	4.83	4.29	84	3.52	3.11	2.84	2.42

TABLE 9 (cont'd)

Subj.	Non-stress RC	Non-stress RRC	Stress RC	Stress RRC	Subj.	Non-Stress RC	Non-Stress RRC	Stress RC	Stress RRC
86	3.88	3.45	3.60	3.28	115	3.67	2.66	3.41	2.65
87	3.96	3.53	2.61	2.15	120	3.58	3.06	3.24	2.65
88	4.21	3.25	2.78	2.15	121	3.08	2.53	3.29	2.57
89	5.47	4.33	5.33	4.72	122	2.40	2.14	2.47	2.13
90	3.90	2.48	3.52	3.17	123	5.42	3.41	5.37	4.90
94	1.78	1.55	2.30	1.86	124	3.95	3.37	2.60	2.43
95	2.84	2.23	3.13	2.53	125	7.46	5.96	3.93	3.67
97	3.97	2.88	3.24	2.82	132	4.12	3.89	3.26	2.51
98	10.78	11.00	6.81	6.04	134	4.54	3.77	4.84	3.59
99	2.50	2.21	2.94	2.29	136	3.19	2.68	2.57	2.14
100	2.45	2.23	2.32	1.99	137	9.00	7.96	6.70	6.57
102	3.31	3.04	2.61	1.98	138	3.43	1.21	4.07	3.63
104	4.69	3.78	4.26	3.77	141	6.23	5.17	9.87	8.90
108	4.46	4.04	2.18	1.91	143	7.74	7.62	5.41	4.47
109	4.90	3.96	4.57	3.84	144	1.54	1.37	1.83	1.50
110	2.82	2.20	3.50	2.84	145	4.67	4.54	4.44	4.34
111	2.37	1.92	3.84	3.24	147	5.18	4.38	7.10	6.67
112	4.51	3.92	4.12	3.13	148	1.56	1.26	2.54	1.91
113	5.84	5.57	4.43	3.87	149	4.58	3.98	4.75	4.43
114	2.64	2.44	3.34	2.73	151	1.63	1.35	2.10	1.68

and the lowest 25% of each group was categorized as "stabile." In this manner it was felt that overlap between the sub-groups would be minimized, resulting in relatively more "pure" groups.

Table 10 summarizes the range of the change parameters for each of the eight distributions of scores. Inspection of the data contained in Table 10 indicates that there is considerable disparity between the labile and stabile range of rate of change and rate of rate of change parameters for each of the four methods of categorization.

TABLE 10

RANGE OF RATE OF CHANGE PARAMETERS BY GROUP

Group	Labile		Stabile	
	High	Low	High	Low
RC Non-Stress	10.78	4.69	2.50	1.23
RRC Non-Stress	6.16	3.92	2.14	1.21
RC Stress	9.87	4.28	2.57	1.29
RRC Stress	8.90	3.77	2.13	0.42

The distributions of scores of the labile and stabile groups were compared for each of the four methods of categorization. These data are summarized in Table 11.

The mean rate of change for the labile group under non-stress conditions was 4.30 beats per minute higher than that of the stabile group, while the mean rate of change under stress conditions of the labile group was 3.45 higher than that of the stabile group. The mean rate of rate of change for the labile group was 3.92 higher than that of the stabile group, under non-stress conditions, while it was 3.22 higher for the labile group than the stabile group under stress conditions. When these distributions of scores were compared by means of the <u>t</u> test, the differences between the mean scores all proved to be highly statistically significant ($p < .001$ in each instance). This finding, however, is hardly surprising, since the extremes of the total group of subjects were utilized for comparisons.

TABLE 11

MEANS, STANDARD DEVIATIONS, AND t'S FOR LABILE AND STABILE GROUPS FOR FOUR CHANGE INDEXES

Index	Labile		Stabile		t	p
	Mean	S.D.	Mean	S.D.		
RC Non-Stress	6.34	1.65	2.04	.39	11.03	< .001
RC Stress	5.65	1.13	2.20	.32	12.78	< .001
RRC Non-Stress	5.60	2.04	1.68	.33	8.17	< .001
RRC Stress	4.99	1.22	1.77	.35	11.10	< .001

In summary, then, four separate groups of stabile and labile subjects were formed, on the basis of rate of change and rate of rate of change measures under non-stress and stress conditions. The mean rate of change and mean rate of rate of change measures in each instance were significantly different between the labile and stabile sub-groups. These stabile and labile groups were then compared as to their performance on the experimental tasks.

RESULTS AND CONCLUSIONS

First, the relationships between the rate of change and rate of rate of change parameters were determined. Second, the groups categorized as stabile and labile upon indexes obtained under non-stress and stress conditions were compared upon the perceptual motor, and cognitive tasks. These results are presented in the following pages.

Relationships Between Rate of Change and Rate of Rate of Change Parameters

The relationships between the rate of change and rate of rate of change parameters for the total groups of 80 subjects were determined by computation of Spearman product-moment correlations. First, the correlation between the non-stress rate of change and rate of rate of change indexes was computed. Second, the correlation between the rate of change and rate of rate of change indexes under stress conditions was computed. Third, the correlation between the non-stress rate of change and the rate of change under stress conditions was computed. Fourth, the correlation between the non-stress rate of rate of change and the rate of rate of change under stress conditions was computed. These data are summarized in Table 12. Inspection of the data contained in Table 12 indicates that all of the correlations are significant beyond the .001 level. There is a very high degree (almost perfect) of correlation between RC and RRC for both non-stress and stress conditions. The degree of relationship between the stress and non-stress RC and RRC is moderate.

TABLE 12

CORRELATIONS BETWEEN RATE OF CHANGE PARAMETERS
(N = 80)

Parameter	Correlation
Non-Stress RC and RRC	.96
Stress RC and RRC	.97
Non-Stress RC and Stress RC	.66
Non-Stress RRC and Stress RRC	.62

From the data summarized in Table 12, it is concluded that:

(1) Rate of change of heart rate under non-stress conditions is almost perfectly positively correlated with rate of rate of change of heart rate under non-stress conditions.

(2) Rate of change of heart rate under stress conditions is almost perfectly positively correlated with rate of rate of change of heart rate under stress conditions.

(3) Rate of change of heart rate under non-stress conditions is significantly ($p < .001$) and moderately positively correlated with rate of change of heart rate under stress conditions.

(4) Rate of rate of change of heart rate under non-stress conditions is significantly ($p < .001$) and moderately positively correlated with rate of rate of change of heart rate under stress conditions.

TABLE 13

PERCEPTUAL TASK SCORES UNDER NON-STRESS AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	3	9	38	5	2
4	8	3	40	8	0
5	9	3	41	4	1
8	9	1	45	0	3
9	12	2	47	2	1
10	15	11	49	4	2
13	6	2	55	7	8
14	8	2	57	3	1
16	5	2	58	2	6
17	10	5	60	5	12
19	4	1	62	10	1
20	9	4	63	1	1
23	2	18	67	3	9
24	13	12	70	8	5
25	5	3	71	2	2
26	9	4	74	2	3
27	8	6	77	6	23
29	6	9	78	7	5
32	3	2	81	4	1
34	7	5	84	2	2

TABLE 13 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
86	7	4	115	2	3
87	12	9	120	5	0
88	5	2	121	3	0
89	4	28	122	3	1
90	8	7	123	2	7
94	12	14	124	1	1
95	5	14	125	6	0
97	6	0	132	7	5
98	4	6	134	5	1
99	3	1	136	8	11
100	3	2	137	4	6
102	1	4	138	3	4
104	9	1	141	4	10
108	9	5	143	3	2
109	9	7	144	8	2
110	3	13	145	2	3
111	7	5	147	1	0
112	5	0	148	2	1
113	2	1	149	3	6
114	4	5	151	14	9

Task Performance

The results of the comparisons of the stabile and labile groups on the three experimental tasks are presented in the following pages.

Performance of Stabile and Labile Subjects on the Perceptual Task

The hypotheses relative to the differences in perceptual functions between the stabile and labile groups of subjects under stress were explored by measuring performance on the perceptual task, under non-stress conditions first, and then second, under stress conditions. These data are summarized in Table 13. The score on the first condition was subtracted from the second, and the resulting algebraic difference then was the index of change in perceptual functions. The mean difference scores between the non-stress and stress conditions, the standard deviation, standard error, differences in means, the standard error of the difference, and the resultant *t* are summarized in Table 14 for both labile and stabile subjects for each of the four experimental orderings of the subjects.

The scores reported are the mean errors made by the subject, so that a negative difference score will indicate a decrease in errors from the non-stress to the stress situation, while a positive difference score would indicate an increase in errors. Thus, a negative score indicates better performance, while a positive score indicates worse performance under stress conditions. In order to assess the significance of the *t*, one-tailed tests were utilized, since the direction of the difference was predicted.

TABLE 14

DATA RELATIVE TO DIFFERENCES BETWEEN MEAN PERCEPTUAL TASK SCORE INDEXES OF STABILE AND LABILE GROUPS

Group	Stabile Mean	Stabile S.D.	Labile Mean	Labile S.D.	Mean Diff.	SED	t	p
Non-stress RC	-3.70	3.24	1.00	6.53	4.70	1.67	2.81	$< .005$
Stress RC	-1.85	3.10	1.70	5.92	3.55	1.53	2.32	$< .025$
Non-Stress RRC	-2.50	5.39	1.25	6.17	3.75	1.88	1.99	$< .05$
Stress RRC	-2.75	3.25	1.05	6.64	3.80	1.69	2.25	$< .05$

Inspection of the data contained in Table 14 reveals that in every instance there is a statistically significant difference between the mean difference from the non-stress to stress score of the stabile as compared with that of the labile group. The labile group in every instance shows a decrease in accuracy of response to a perceptual stimulus under stress, while the stabile group does not.

Accordingly, it is concluded that:

1. When the subjects are divided into stabile and labile subgroups on the basis of the RC under non-stress conditions, the labile group shows greater decrement on the perceptual task under stress than does the stabile group.

2. When the subjects are divided into stabile and labile subgroups on the basis of the RC under stress conditions, the labile group shows greater decrement on the perceptual task under stress than does the stabile group.

3. When the subjects are divided into stabile and labile subgroups on the basis of the non-stress RRC, the labile group shows greater decrement on the perceptual task under stress than does the stabile group.

4. When the subjects are divided into stabile and labile subgroups on the basis of the stress RRC, the labile group shows greater decrement on the perceptual task under stress than does the stabile group.

Examination of the data indicates that there is a greater discrepancy in mean difference scores depending upon how the labile and stabile groups are formed. In order of magnitude of difference between the labile groups, the ranking is:

1. RC on the non-stress condition (D = 4.70)
2. RRC on the stress condition (D = 3.80)
3. RRC on the non-stress condition (D = 3.75)
4. RC on the stress condition (D = 3.55)

Thus, the magnitude of the mean difference on the perceptual task between the stabile and labile groups is greatest when the groups are formed upon the basis of the RC as opposed to the RRC measure, and further that the greatest mean difference is exhibited when the groups are formed upon the basis of the RC under non-stress conditions.

TABLE 15

TOT SCORES UNDER NON-STRESS AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	5.93	16.97	38	.57	5.80
4	15.31	18.12	41	14.46	27.22
5	8.15	23.95	45	5.40	16.37
8	9.93	24.43	47	12.92	30.90
9	3.46	9.91	49	7.20	15.86
10	8.57	10.82	55	13.91	35.90
13	10.54	28.03	57	11.38	22.31
14	9.61	24.13	58	8.13	15.76
16	7.48	24.20	60	15.97	20.00
17	9.30	21.81	62	1.70	7.17
19	10.97	17.44	63	8.63	13.13
20	2.93	5.24	67	12.88	25.25
23	22.18	33.56	70	26.08	40.19
24	8.08	22.39	71	18.37	22.75
25	13.29	23.26	74	11.04	30.14
26	7.81	14.43	77	3.07	21.36
27	3.20	9.67	78	16.69	34.39
29	7.75	21.28	81	5.75	23.73
32	7.90	28.46	84	.77	6.30
34	6.81	16.48	86	15.05	26.77

TABLE 15 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
87	17.32	39.36	115	9.42	26.00
88	5.61	19.81	120	9.67	16.86
89	13.61	33.12	121	24.35	45.91
90	1.32	11.09	122	6.97	19.07
91	5.75	23.73	123	8.35	27.99
94	14.54	31.99	124	17.93	38.81
95	5.95	14.20	125	8.06	17.03
97	4.20	11.01	132	5.61	16.91
98	19.80	25.92	134	9.14	21.11
99	13.11	30.57	136	14.56	26.65
100	13.14	20.08	137	.67	10.99
102	5.22	15.55	138	13.90	19.74
104	12.79	34.19	141	3.81	8.34
108	17.31	35.41	143	6.41	27.38
109	15.54	25.88	144	2.14	3.57
110	13.30	24.40	145	11.76	19.22
111	13.24	30.72	147	7.17	11.42
112	9.70	19.25	148	4.08	15.03
113	3.27	7.92	149	5.40	13.08
114	7.94	12.40	151	1.22	5.48

TABLE 16

HIT SCORES UNDER NON-STRESS
AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	72	175	38	7	71
4	181	219	41	168	260
5	105	247	45	170	176
8	104	216	47	165	252
9	46	125	49	92	200
10	112	136	55	154	325
13	124	295	57	141	257
14	118	280	58	93	175
16	101	244	60	158	201
17	111	203	62	24	100
19	116	177	63	110	161
20	43	78	67	167	261
23	243	348	70	223	348
24	90	198	71	163	223
25	143	216	74	113	269
26	87	147	77	49	198
27	40	132	78	163	313
29	103	255	81	67	268
32	94	257	84	14	9
34	85	170	86	185	280

TABLE 16 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
87	158	301	115	100	256
88	159	200	120	104	184
89	124	256	121	181	315
90	22	121	122	86	207
91	67	268	123	102	254
94	167	322	124	171	278
95	80	167	125	86	182
97	54	131	132	76	207
98	170	232	134	122	227
99	134	268	136	166	276
100	133	210	137	11	127
102	68	173	138	156	224
104	130	273	141	35	101
108	174	305	143	82	293
109	121	237	144	31	51
110	115	219	145	137	205
111	138	248	147	82	142
112	109	160	148	54	194
113	42	94	149	72	157
114	101	156	151	17	65

TABLE 17

TOT/HIT SCORES UNDER NON-STRESS AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	.08	.10	38	.08	.08
4	.09	.08	40	.09	.08
5	.08	.10	41	.09	.11
8	.10	.11	45	.03	.09
9	.08	.08	47	.10	.12
10	.08	.08	49	.08	.08
13	.09	.10	55	.09	.11
14	.08	.09	57	.08	.09
16	.07	.10	58	.09	.09
17	.08	.11	60	.10	.10
19	.10	.10	62	.07	.07
20	.07	.07	63	.08	.08
23	.09	.10	67	.08	.08
24	.09	.11	70	.12	.12
25	.09	.11	71	.11	.10
26	.09	.10	74	.10	.11
27	.08	.07	77	.06	.11
29	.08	.08	78	.10	.11
32	.08	.11	81	.09	.09
34	.08	.10	84	.06	.07

TABLE 17 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
86	.09	.10	115	.09	.10
87	.11	.13	120	.09	.09
88	.10	.10	121	.14	.15
89	.11	.13	122	.08	.09
90	.06	.09	123	.08	.11
94	.09	.10	124	.11	.14
95	.07	.09	125	.09	.09
97	.08	.08	132	.07	.08
98	.12	.11	134	.08	.09
99	.10	.11	136	.09	.10
100	.10	.10	137	.06	.09
102	.08	.09	138	.09	.09
104	.10	.13	141	.11	.08
108	.10	.12	143	.08	.09
109	.13	.11	144	.07	.07
110	.12	.11	145	.09	.09
111	.10	.12	147	.09	.08
112	.09	.12	148	.08	.08
113	.08	.08	149	.08	.08
114	.08	.08	151	.07	.08

Performance of the Stabile and Labile Subjects on the Motor Task

As in the case of the perceptual task, the assessment of motor functions was accomplished by securing measures of motor functions, first under non-stress, and second, under stress conditions. Three indexes derived from the tracking task were utilized: (1) the total time on target (TOT); (2) the total number of hits on the target (HIT), and (3) the total time on target divided by the number of target hits (TOT/HIT). The non-stress and stress data for each of these indexes for each subject are presented in Tables 15, 16, and 17 respectively.

The index of change in performance on the motor task was determined by subtracting the score under stress conditions from those obtained under non-stress conditions. Distributions of these indexes were then calculated for each of the four indexes. The significance of the mean differences between the stabile and labile groups for each of the four methods of subject categorization were then determined by means of the *t* test. These data are summarized in Tables 18, 19, and 20 respectively.

Inspection of the data summarized in Table 18 indicates that in no instance is the mean difference in TOT performance from non-stress to stress of the stabile group significantly different from that of the labile group, regardless of how the groups were categorized. Accordingly, it is concluded that:

(1) When the subjects are categorized on the basis of RC obtained under non-stress conditions, the mean difference in TOT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(2) When the subjects are categorized on the basis of RC obtained under stress conditions, the mean difference in TOT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(3) When the subjects are categorized on the basis of RRC obtained under non-stress conditions, the mean difference in TOT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

(4) When the subjects are categorized on the basis of RRC obtained under stress conditions, the mean difference in TOT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

Inspection of the data contained in Table 19 indicates that in no instance is the mean difference in HIT performance from non-stress to stress of the stabile group significantly different from that of the labile group, regardless of how the groups were categorized. Accordingly, it is concluded that:

TABLE 18

DATA RELATIVE TO DIFFERENCE SCORES ON TOT OF STABILE AND LABILE SUBJECTS BY GROUP

Group	Stabile		Labile		Mean			
	Mean	S.D.	Mean	S.D.	Diff.	SED	t	p
Non-Stress RC	10.42	5.43	11.97	6.28	1.55	1.90	.82	> .05
Stress RC	9.33	5.16	12.09	6.67	2.76	1.94	1.42	> .05
Non-Stress RRC	10.06	5.24	11.42	5.61	1.36	1.76	.78	> .05
Stress RRC	9.99	4.99	12.17	6.16	2.19	1.81	1.21	>.05

TABLE 19

DATA RELATIVE TO DIFFERENCE SCORES ON HIT OF STABILE AND LABILE SUBJECTS BY GROUP

Group	Stabile		Labile		Mean			
	Mean	S.D.	Mean	S.D.	Diff.	SED	t	p
Non-Stress RC	98.70	10.10	106.90	12.09	8.20	15.75	.52	> .05
Stress RC	92.25	11.36	112.50	10.28	20.25	15.32	1.32	> .05
Non-Stress RRC	96.80	10.01	103.35	11.67	6.55	15.38	.43	> .05
Stress RRC	97.70	9.17	112.95	10.53	15.25	13.96	1.09	>.05

(1) When the subjects are categorized on the basis of RC obtained under non-stress conditions, the mean difference in HIT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(2) When the subjects are categorized on the basis of RC obtained under stress conditions, the mean difference in HIT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(3) When the subjects are categorized on the basis of RRC obtained under non-stress conditions, the mean difference in HIT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

(4) When the subjects are categorized on the basis of RRC obtained under stress conditions, the mean difference in HIT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

Inspection of the data contained in Table 20 indicates that in no instance is the mean differences in TOT/HIT performance from non-stress to stress conditions of the stabile group

TABLE 20

DATA RELATIVE TO DIFFERENCE SCORES ON TOT/HIT OF STABILE AND LABILE SUBJECTS BY GROUPS

Group	Stabile		Labile		Mean Diff.	SED	t	p
	Mean	S.D.	Mean	S.D.				
Non-Stress RC	.01	.01	.0095	.02	.0005	.005	.100	>.05
Stress RC	.008	.009	.008	.005	.0000	.002	.000	>.05
Non-Stress RRC	.0095	.01	.009	.02	.0005	.01	.05	>.05
Stress RRC	.0085	.01	.0075	.015	.001	.015	.067	>.05

significantly different from that of the labile group, regardless of how the groups were categorized. Accordingly, it is concluded that:

(1) When the subjects are categorized on the basis of RC obtained under non-stress conditions, the mean difference in TOT/HIT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(2) When the subjects are categorized on the basis of RC obtained under stress conditions, the mean difference in TOT/HIT from stress to non-stress conditions for the stabile subjects is not significantly different from that of the labile subjects.

(3) When the subjects are categorized on the basis of RRC obtained under non-stress conditions, the mean difference in TOT/HIT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

(4) When the subjects are categorized on the basis of RRC obtained under stress conditions, the mean difference in TOT/HIT from stress to non-stress conditions of the stabile subjects is not significantly different from that of the labile subjects.

Performance of the Stabile and Labile Subjects on the Cognitive Task

The Obscure Figures Test, which was used to explore cognitive functions, was first given to the subject under conditions of non-stress and then repeated under conditions of stress. These scores, by subject are presented in Table 21.

TABLE 21

OBSCURE FIGURES TEST SCORES UNDER
NON-STRESS AND STRESS CONDITIONS
(N = 80)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
2	49	41	38	54	53
4	51	47	40	45	45
5	53	49	41	49	43
8	43	44	45	55	54
9	66	69	47	46	47
10	50	49	49	45	43
13	55	54	55	41	41
14	54	51	57	46	46
16	55	56	58	54	60
17	49	51	60	48	47
19	49	49	62	42	40
20	48	52	63	47	48
23	52	48	67	47	41
24	51	56	70	51	48
25	73	72	71	46	43
26	48	47	74	46	43
27	46	50	77	46	44
29	56	56	78	49	45
32	41	40	81	45	46
34	49	51	84	49	54

TABLE 21 (cont'd)

Subj.	Non-Stress	Stress	Subj.	Non-Stress	Stress
86	52	52	115	42	42
87	46	47	120	44	47
88	51	44	121	42	42
89	48	44	122	45	49
90	43	45	123	49	47
94	51	44	124	41	43
95	41	40	125	48	48
97	50	49	132	46	44
98	44	46	134	49	47
99	47	51	136	53	45
100	43	44	137	45	41
102	45	45	138	40	40
104	48	46	141	50	43
108	48	45	143	55	55
109	49	43	144	46	43
110	45	41	145	43	42
111	49	45	147	51	50
112	47	44	148	47	44
113	45	40	149	48	45
114	49	47	151	41	45

The stress score was subtracted from the non-stress score in order to yield an index of change in cognitive functioning from non-stress to stress conditions. Distributions of these resulting scores were then calculated for each of the four stabile and four labile groups of subjects. The significance of the mean difference between the stabile and labile groups was then determined by means of the t-test. These data are summarized in Table 22.

TABLE 22

DATA RELATIVE TO DIFFERENCE ON COGNITIVE TASK INDEXES OF STABILE AND LABILE SUBJECTS BY GROUP

Group	Stabile		Labile		Mean			
	Mean	S.D.	Mean	S.D.	Diff.	SED	t	p
Non-Stress RC	- .35	2.90	-2.10	3.21	1.75	.998	1.75	$<.05$
Stress RC	-1.20	3.30	-1.70	3.62	.50	1.123	.45	$>.05$
Non-Stress RRC	- .80	2.80	-2.15	3.20	1.35	.975	1.38	$>.05$
Stress RRC	- .95	2.99	-1.80	3.46	.85	1.048	.81	$>.05$

Inspection of the data included in Table 22 reveals that in every instance, cognitive functions, as measured by the Obscure Figures Test, showed a decrement under stress conditions for both the stabile and labile groups. However, this decrement was greater in every instance for the labile as opposed to the stabile groups. This tendency was in accord with the experimental hypotheses. But, this difference was not statistically significant for the groups formed upon the basis of the RC and RRC measures taken under stress conditions nor for the group formed upon the basis of the RRC measures taken under non-stress conditions ($p > .05$). However, the difference was statistically significant ($p < .05$) between the stabile and labile groups when categorized by the RC obtained under non-stress conditions. The fact that, in each other instance, that the difference is in the predicted direction serves to reinforce the conclusion that the labile subjects show a greater decrement under stress conditions than do the stabile subjects in cognitive functioning. Accordingly, from the preceding data, it is concluded that:

(1) When the subjects are categorized on the basis of RC obtained under non-stress conditions, the labile subjects show greater decrement under stress in cognitive functions than do the stabile subjects.

(2) When the subjects are categorized on the basis of RC obtained under stress conditions, the labile subjects do not show greater decrement in cognitive functions under stress than do the stabile subjects. The difference, however, even though not statistically significant, is in the predicted direction, with the labile subjects showing greater decrement than the stabile subjects in cognitive functions.

(3) When the subjects are categorized on the basis of RRC measures obtained under non-stress conditions, the labile subjects do not show greater decrement in cognitive functions under stress than do the stabile subjects. The difference, however, even though not statistically significant is in the predicted direction, with the labile subjects showing greater decrement than the stabile subjects in cognitive functions.

(4) When the subjects are categorized on the basis of RRC measures obtained under stress conditions, the labile subjects do not show greater decrement in cognitive functions under stress than do the stabile subjects. The difference, however, even though not statistically significant, is in the predicted direction, with the labile subjects showing greater decrement than the stabile subjects in cognitive functions.

DISCUSSION

The correlations between RC and RRC under stress and non-stress conditions were almost perfect. Under non-stress conditions the correlation was .96, and under stress conditions it was .97. Thus it is evident that the relationships between RC and RRC under both conditions of non-stress and stress are so high that there is little value, in accord with the results of the study, in computing the RRC index in addition to computing the RC index.

It was found that when the subjects were categorized as stabile or labile on the basis of the RC obtained under non-stress conditions, significant differences were demonstrated between the groups on the perceptual and cognitive tasks, but not on the motor task. When the subjects were categorized as stabile or labile on the basis of the RC obtained under stress conditions, significant differences were demonstrated on the perceptual task only, but not on the motor nor on the cognitive tasks, although the difference between performance of the stabile and labile subjects under stress did approach statistical significants. Therefore, it is concluded that the RC obtained under the non-stress conditions is, at least in the present study, the most effective index for categorizing the subject as being either stabile or labile.

It is concluded that when the subjects are categorized as stabile or labile on the basis of the rate of change of heart beat rate obtained under resting autonomic activity, that labile subjects show greater decrement under stress in cognitive functions than do the stabile subjects. When the labile subjects are placed in a stress situation, they show a reduction in the capacity to be innovative. Perceptual material is not assimilated as adequately, and their capacities for imagination and ingenuity are reduced. Consequently, in the labile subjects, there is a constriction in the capacity for dealing with input data in new ways. Both the labile and stabile subjects showed such a constriction under the stress conditions, but the constriction was more stringent for the labile than it was for the stabile group of subjects.

From the results of the study, it is concluded that the labile subjects respond more erroneously to peripheral visual stimuli than do the stabile subjects when they are placed under conditions of stress. It appears, therefore, that the labile subjects tend to be more impulsive, and that they over-react to environmental stimuli more than do the labile subjects when an already existing arousal state is augmented by environmental stress. Inhibitory behavior is not as readily manifested by the labile person, and he manifests a readiness to react and to discharge through motoric acts regardless of the appropriateness of the response.

The study indicates that resting cardiac lability (as measured by non-stress RC) is related to response error under stress. This finding tends to be in accord with the finding of Lacey and Lacey that "autonomic variation is positively related to quantitative measures of hyperkinetic and impulsive aspects of behavior."[1] They offer, as one theoretical explanation of the phenomenon, that autonomic activity may feed back to the brain stem and cortex via viceral afferents or via the reticular activating formation. Further, they state that autonomic activity may influence cortical activity via the pressure sensitive receptors of the carotid sinus and aortic arch. But in any event, regardless of whether the feedback is achieved through visceral afferents, reticular formations, or baroreceptors, Lacey and Lacey state that the resulting feedback ultimately means that the autonomic response may then become a stimulus, which is directed to cortical and subcortical structures, and serves to result in energizing and adaptive functions which adjust receptivity and reactivity to the needs of the moment. In essence, therefore, Lacey and Lacey conceptualize the autonomic response itself as being a stimulus, feeding back to the cortex, and that this would explain the higher incidence of erroneous responses by labile RC subjects.

A somewhat different point of view is suggested by Duffy in her concepts of activation. But Lacey and Lacey agree to some extent with Duffy, in that they state that "autonomic measurements are simply not metered indicators of affect, they reveal the operation of an activating or 'energy mobilizing' system."

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[1] Lacey, J. I. and Lacey, B. C. The relationship of resting autonomic activity to motor impulsivity, In H. Solomon, S. Cobb, and W. Penfield (Eds.) The Brain and Human Behavior. Baltimore: Wilkins & Wilkins Co., 1958, p. 198.

According to Duffy, "activation" is a function of the reticular formation, while inhibiting control is a function of the cortex, which serves to maintain the activation level of the organism at an opitmum and stabilized level (in accord with homeostatic principles).[1] Individuals vary as to the degree to which inhibiting controls are maintained. When they are reduced, the behavior becomes impulsive, and erroneous responses are manifested. The more complex the behavior of the organism, the greater is the probability of a faulty response when cortical inhibiting controls are not maintained. Thus, in accord with the activation theory proposed by Duffy, the individual with a labile RC of heart rate beat is an individual who is unable to maintain adequate inhibiting cortical control over the high-level activating activity of the reticular formation.

The findings indicate the need for continued monitoring of RC during space flights. The importance of continued examination of cardiovascular responses has also been given a role of paramount importance by Russian space investigators, who feel that the matter is so important that it justifies the

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[1] See:

a. Malmo, R. B. Activation: A neurophysiological dimension. Psychol. Rev., 1959, 66, 367-386.

b. Berlyne, D. C. Conflict, arousal and curiosity. New Your: McGraw Hill, 1960.

c. Duffy, E. The psychological significance of the concept of "arousal" or "activation." Psychol. Rev., 1957, 64, 265-275.

d. Duffy, E. Activation and behavior. New York: Wiley, 1962.

establishment of a specific branch of science, that of "space cardiology."[1] Parin, et al. have noted that changes in the rhythmical activity of the heart, the cardiac rhythm, are mediated via centers of the vagus and sympathetic nerves. It fluctuates during space flight according to a specific pattern. There is a typical delayed normalization of the rhythm after the action of acceleration, relative bradycardia, and increased variability of pulse rate. Parin, et al. concluded that during weightlessness an increase in tone of the parasympathetic part of the vegetative nervous system takes place, with the central nervous system playing an important role in the development of the adaptive responses of the cardiovascular system, with the responses resulting from excitation of the sympathetic nerves being of highest importance. It would be therefore of great interest and importance to study fluctuations in rate of change parameters at various time intervals throughout an extended space mission, and to attempt to relate these to behavioral manifestations in diverse areas. This would be the primary focus of a continuing study.

But, regardless of the theoretical structure which is espoused, the results of the study are clearly indicative of the fact that individuals with labile RC of heart beat rate react to a stress situation with more impulsive and error-laden

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[1] Parin, V., Bayevsky, R., Gazenko, O. Heart and circulation under space conditions. Acta Cardiologica, 1965, 20, 105-129.

behavior than do persons with a more stabile RC. Furthermore, the labile subject also shows more decrement in cognitive functions under stress than does the stabile subject. Consequently, first, the results are important for the selection of individuals for space flight activities. Second, for the reasons specified, there is also a demonstrated need for the monitoring of the heart rate parameter during flight, so as to be able to predict and possibly obviate adverse performance of the astronaut.

The findings of the present study, which is the first undertaken in this new area, are sufficiently striking and of such importance that they make additional investigation mandatory.

As pointed out previously, there is need for research to explore the relationships between fluctuations in rate of change parameters during specific time intervals in extended space flight to various behavioral reactions. Also, the differences in decrements in task performance under stress of labile and stabile subjects who do not show reactions to stress by increased catecholamine production need to be studied, so that the results of this study be more meaningful. This additional study would provide us with more valid normative data as to lability of rate of change parameters. There is one further study which is quite provocative and which would probably be of great value. This would be to attempt to program the subject so as to enable him to reduce the lability of rate of change of heart rate beat in a conscious and volitional manner; that is, to condition an introspective response. Then, if this could be accomplished, further research could be directed towards exploring the relationships between such volitional reduction in lability of rate of change to reduction in decrement in task performance under stress. The results of the present study stress the need for continuing research.

SUMMARY

The major purpose of the study was to validate new parameters: the rate of change and the rate of rate of change of heart beat rate. The central hypothesis was that subjects categorized as having a labile rate of change of heart beat rate would do more poorly under stress on various experimental tasks than would individuals categorized as having a stabile rate of change. The rate of change and the rate of rate of change indexes (the independent variables of the study) were derived in accord with the techniques proposed by Townsend and Lindsey. The experimental tasks (the dependent variables of the study) were:

(1) A perceptual task (measured by means of a visual-perceptual task)

(2) A psychomotor task (measured by means of a tracking task)

(3) A cognitive task (measured by means of the Obscure Figures Test)

The stress situation was composed of two major elements applied simultaneously:

(1) Physiological stress (induced by an electric shock technique)

(2) Psychological stress (induced by threat of failure and working to time limits techniques)

It was required that each subject included in the final subject pool show evidence of being stressed by the experimental situations. Two criteria of stress were utilized:

(1) A physiological criterion (an increase in urinary catecholamines from the non-stress to the stress situation)

(2) A psychological criterion (an increase in Subjective Stress Scale score from the non-stress to the stress situation)

It was required that each subject satisfy both of these criteria in order to be included in the final sample.

Every subject was required to meet all of the following criteria:

(1) Be at least 19 years of age.

(2) Be a science or engineering major

(3) Be free from any perceptual or medical defect that might interfere with the study

(4) Score above the 80th percentile on the Otis Self-Administering Test of Mental Ability, Higher Examination, Form A

(5) Attain a score of 10 or less on the Cornell Index

(6) Show an increase in urinary catecholamine excretion from the non-stress to the stress situation

(7) Show an increase in the Subjective Stress Scale score from the non-stress to the stress situation

A total of 151 persons satisfied criteria 1, 2, and 3. Of these, 144 also satisfied, in addition, criteria 4 and 5.

The experimental situation extended over a two-day period. On the first experimental day (the non-stress situation) the rate of change and rate of rate of change measures were secured for each potential subject meeting the basic selection criteria of intelligence, emotional stability, physical condition, age, and college field of specialty. The three experimental tasks were administered (perceptual, psychomotor, and cognitive). Then the Subjective Stress Scale was completed by the subject, and a sample of urine obtained for catecholamine determination.

On the second experimental day (the stress situation) the subject was exposed to both physiological and psychological stress, the three experimental tasks were again presented, and the rate of change and rate of rate of change indexes determined. The Subjective Stress Scale was readministered, and again a sample of urine was obtained for catecholamine determination. Each subject thus served as his own control.

When the stress validation measures of the second experimental day were determined, (Subjective Stress Scale and urinary catecholamines) all subjects who did not show an increase in both of these measures from the non-stress to the stress situation were excluded from the study. Out of the 124 subjects completing the experimental tasks, 80 satisfied all of the criteria, and so finally were qualified as subjects.

The relationships between the rate of change and rate of rate of change parameters were determined for these 80 subjects. The Pearson product-moment correlations between the various indexes were:

(1) RC non-stress and RC stress: .66

(2) RRC non-stress and RRC stress: .62

(3) RC non-stress and RRC non-stress: .96

(4) RC stress and RRC stress: .97

All of these correlations were statistically significant ($p < .001$). The correlations between the RC and RRC under non-stress and between the RC and RRC under stress conditions were almost perfect in both instances, while those between RC under non-stress and RC under stress, and RRC under non-stress and RRC under stress were at a high moderate level. It should be observed that the measurements for determining these latter two correlations were secured on two successive days. It was concluded that since the correlations between RC and RRC under both non-stress and stress conditions were so high that little would be gained by utilizing the RRC indexes for categorizing the groups.

Four groups of labile and four groups of stabile subjects were then formed upon the basis of the:

(1) Rate of change index under non-stress conditions

(2) Rate of change index under stress conditions

(3) Rate of rate of change index under non-stress conditions

(4) Rate of rate of change index under stress conditions

Change in performance of the stabile subjects fron non-stress to stress conditions then was compared with that of the labile subjects for each of these four techniques of categorization.

When the subjects were categorized as stabile or labile upon the basis of rate of change of heart rate under non-stress conditions, and the shift by the two groups from non-stress to stress conditions compared on the experimental tasks, it was concluded that:

(1) The labile subjects performed significantly more poorly under stress than did the stabile subjects on the perceptual task.

(2) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the motor task.

(3) The labile subjects performed significantly more poorly under stress than did the stabile subjects on the cognitive task.

When the subjects were categorized as stabile or labile upon the basis of rate of change of heart rate under stress conditions, and the non-stress to stress shifts on the experimental tasks compared, it was concluded that:

(1) The labile subjects performed significantly more poorly under stress than did the stabile subjects on the perceptual task.

(2) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the motor tasks.

(3) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the cognitive tasks.

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(2) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the motor tasks.

(3) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the cognitive tasks.

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(1) The labile subjects performed significantly more poorly under stress than did the stabile subjects on the perceptual task.

(2) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the motor tasks.

(3) The labile subjects did not perform significantly more poorly under stress than did the stabile subjects on the cognitive tasks.

The results were discussed in terms of the cortical inhibition theory suggested by Lacey and Lacey, and the activation theory proposed by Duffy. Contributions of Russian space scientists were presented in order to support the conclusion that assessment of cardiovascular functions during space flight is of importance.

The results of the study clearly indicate:

(1) The need for determining the rate of change parameters in the selection of persons for space flight activities.

(2) The need for monitoring the rate of change parameters during space flight, so as to predict possible adverse actions of the astronaut.

Implications of the study were presented and the need for further validation research of the rate of change of heart beat rate parameters was stressed.

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